In-season Harvest and Effort Estimates for 2016 Kuskokwim River Subsistence Salmon Fisheries During Block Openers

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ABSTRACT

Management of the Kuskokwim River Chinook salmon (*Oncorhynchus tshawytscha*) subsistence fishery has historically been conducted with minimal in-season harvest and run strength information. Because of this lack of information, it is challenging to make well-supported and defensible decisions regarding fishing opportunities to simultaneously achieve conservation and harvest objectives, particularly during years of weak runs. In response to an anticipated weak 2016 Kuskokwim River Chinook salmon run, the United States Fish and Wildlife Service in collaboration with the Kuskokwim River Inter-Tribal Fisheries Commission, the Orutsararmiut Native Council, and several other villages on the Kuskokwim River, collected data to produce in-season subsistence salmon harvest estimates from that portion of the Kuskokwim River within the boundaries of the Yukon Delta National Wildlife Refuge. We estimated the total subsistence salmon harvest was 80,443 (49,883 – 122,070) during four fishing opportunities between June 12 and July 2, 2016. Most salmon harvested were Chinook (28,019; 18,878 – 39,774) followed closely by chum (27,398; 16,157 – 43,146), and sockeye (25,026; 14,848 – 39,150). Methodologies developed during this study should be useful to structure future in-season efforts to estimate subsistence salmon harvest on the Kuskokwim River as well as other fisheries with similar characteristics.

INTRODUCTION

In-season management of Kuskokwim River salmon fisheries is undertaken in the face of a severe lack of information. In order to manage in a fully-informed way, a manager would require continuous and accurate information on run timing, harvest, and escapement. With this knowledge, it would then be possible to know how much of the run is yet to come, how much escapement potential remains, and how many more fish can be harvested. In-season management of Kuskokwim River salmon has historically been conducted with very little of this information, and has instead relied on indices of run abundance (which are confounded by run-timing) to inform decision-making. This document presents methodology and results from a newly-developed technique to estimate salmon harvest in-season and resulting from short-duration subsistence fishing opportunities. Timely in-season subsistence harvest estimates have only rarely been available (i.e., 2015) for in-season management consideration, and are arguably the most critical information source necessary to successfully manage weak salmon runs.

In response to an anticipated weak 2016 Kuskokwim River Chinook salmon (*Oncorhynchus tshawytscha*) run, the United States Fish and Wildlife Service (USFWS), by delegation of authority from the Federal Subsistence Board via letter dated Febuary 26, 2015 (Federal Special Action 3-KS-01-16), assumed primary management authority of the Kuskokwim River Chinook and chum salmon subsistence fisheries within the boundaries of

the Yukon Delta National Wildlife Refuge (YDNWR, Figure 1). The Federally-designated manager, along with YDNWR staff and in collaboration with the Kuskokwim River Inter-Tribal Fisheries Commission (KRITFC), designed and implemented a management strategy based on explicit objectives informed by the best available scientific information. The Federal manager and the KRITFC agreed that the subsistence fishery should target a 40,000 Chinook salmon harvest considering an anticipated run size of approximately 140,000 fish and a fundamental objective to assure a spawning escapement of at least 100,000 fish. This escapement objective was further supported by the Kuskokwim River Salmon Management Working Group (KRSMWG, a state of Alaska advisory body) via a motion at their April 20, 2016 meeting calling for a 2016 escapement objective of 85% of the upper bound of the escapement goal range (~102,000 Chinook salmon). Thus, going into the 2016 season, a targeted subsistence harvest of 40,000 Chinook salmon was used as the primary means objective; subject to further revision should in-season assessment information suggest a larger harvest would be warranted. After deliberation on the best tactics to regulate subsistence fishing effort, it was decided that the use of fishing time, area, and gear restrictions would provide an adequate means to manage the fishery. These "block openings" allow for limited harvest opportunity, with periods between openings allowing for harvest estimation and decision-making to identify the nature of subsequent fishing opportunities.

Harvest data from subsistence fisheries on the Kuskokwim River have historically been compiled post-season by the Alaska Department of Fish and Game through voluntary household interviews and harvest calendars (Shelden et al. 2014). Because pursuit of an explicit harvest objective for subsistence salmon fisheries is relatively novel to the Kuskokwim River; in-season harvest estimates were not required or produced before 2015. In 2015, relatively simple harvest estimates were produced based on boat counts and trip interviews conducted during short block openers that year. For the 2016 season, a more complex harvest estimation method was required due to the extended openers (12 hours – 72 hours). The literature regarding how to produce harvest estimates based on effort counts and catch rate information is extensive and well-developed. Bernard et al. (1998) reviewed many of the creel survey methods used throughout Alaska to estimate fishery harvests. However, the methodology for these more typical creel surveys differs from what was required for the Kuskokwim River in 2016. A creel survey for a typical fishery relies on a rigorously-developed sampling protocol designed to obtain representative observations of the fishery behavior over an extended period of time (e.g., several months of open fishing). The Kuskokwim River salmon fisheries in 2016 were implemented using a block opening structure, and thus did not conform to a typical creel survey sampling program. This important difference required a more customized sampling and estimation structure than would be found elsewhere in creel survey applications.

There were four subsistence fishery openers during June 2016 that primarily targeted Chinook salmon within the YDNWR boundaries. The first opener was 12 hours in duration starting at 12:01 pm on June 12 and ending at 11:59 pm (Federal Special Action 3-KS-02-16). The second opener was 24 hours in duration starting at 12:01 pm on June 16 and ending at 11:59 am on June 17 (Federal Special Action 3-KS-04-16). The third opener was 72 hours in duration, starting at 12:01pm on June 21 and ending at 11:59 am on June 24 (Federal Special Action 3-KS-06-16). The fourth opener was 72 hours in duration, starting at 12:01 pm on June 29 and ending at 11:59 am on July 2 (Federal Special Action 3-KS-07-16). Shortly after the fourth opener, managers decided that the subsistence fishery no longer needed to be restricted to conserve Chinook salmon.

Sampling the fishery behavior within the YDNWR boundaries of the Kuskokwim River presents many difficulties related primarily to the size of the system and the remoteness of the villages harvesting salmon. At least 16 villages harvest salmon along the 312 km long mainstem of the Kuskokwim River within the YDNWR boundaries. Coupled with the limitations of

personnel, time, and funding, it is very difficult to obtain harvest information from each stretch of the river. Thus, the harvest estimation approach described here necessitated making assumptions about the representation of the whole fishery by samples taken in a restricted spatial area. Development of methods to reduce the bias in harvest estimates likely resulting from non-representative sampling remains an area for future improvement of the methodology presented here. Still, this report documents the first attempt at producing rigorous in-season estimates for Kuskokwim River subsistence salmon fisheries by (1) stratifying information by geographic and temporal strata, (2) accounting for missed and double counted boats, and (3) quantifying uncertainty in the resulting harvest estimates.

METHODS

Data Sources

The in-season harvest estimation framework that was developed and applied to the 2016 Kuskokwim River salmon season required two primary types of information: (1) an estimate of the total number of fishing trips each day and (2) completed trip interview information documenting gear, fishing location, fishing time, and catch.

Aerial Boat Counts

For each day of each opener, one or more aerial survey flights were flown to count the number of drift boats and set nets fishing within the YDNWR boundaries (Table 1). Flights were scheduled to record boat counts between high and low tide which are the most popular times to fish (Greg Roczicka., pers. comm.). Thus, the number of flights per day varied based on the number of tide cycles within each fishery opening. Flights were not flown during late night tides (i.e., after midnight) or early morning tides (i.e., before 6:00 am) as little fishing effort was anticipated effort during these times.

Weather permitting, flights were flown by departing the Bethel airport, following the river downstream and southwest toward Kuskokwim Bay to Eek Island, then turning upstream and northeast to fly to the village of Aniak which is located just downstream of the YDNWR boundary (Figure 1). This flight path took approximately two hours to complete, not including the return flight to the airport. Boat counts were recorded into approximately 15 river regions demarcated by major landmarks (e.g., villages or tributaries) and then assigned to five strata (Figure 1, strata indicated by letters A-E). Only boats that were actively fishing or were carrying visible net gear were included in the counts. In areas that were counted twice (i.e., once flying downstream, once flying upstream), the maximum of the two counts was used as the boat count for that region. In the event that inclement weather prevented flying the entire YDNWR, the count from the most recent complete count of the missing river strata was used (Table 1).

Completed Trip Interviews

Information from completed fishing trips was collected by personnel from the Orutsararmiut Native Council (ONC) at the Bethel boat harbor and area fish camps. Interviews were intended to be minimally intrusive yet still gain accurate information regarding the trip. The key pieces of information collected by ONC in each interview (indexed by i) included:

- The day fishing occurred (indexed by d)
- The location of the trip (used to place the trip in a geographic stratum, indexed by j)
- The type of net used (drift vs. set, indexed by g).
- The start and end times of the trip ($T_{1,i,d}$ and $T_{2,i,d}$)
- The total number of hours the net was fishing (referred to as “soak hours”; $h_{i,j,d}$)
- The length of the net used (in feet; $L_{i,j,d}$)
- The total harvest of each Chinook, chum, and sockeye salmon (species indexed by s; $C_{s,i,j,d}$)

For the first and second openers, these data were available for the villages of Kalskag and Aniak and was included in the analyses for those

openers. Besides this exception, all interview data came from the Bethel boat harbor and Bethel area fish camps.

Boat Trip Effort Expansion Model

Due to the extended nature of the fishery openings, effort counts made during aerial survey flights did not describe the total number of boat trips fishing during the opener, but rather the number of active boat trips during the flight in each geographic stratum ($A_{c,j,d}$). Thus, an expansion method was needed to account for any boat trips counted on more than one flight and boat trips that occurred but were not observed during any flight. This section describes the methodology that was developed to handle this somewhat unique problem.

Based on the start ($T_{1,i,d}$) and end ($T_{2,i,d}$) times from completed trip interviews and the start ($F_{1,c,d}$) and end ($F_{2,c,d}$) times of the c^{th} flight of day d, it was possible to determine if each trip was active while aerial count c was made. It was determined that four possible scenarios could lead to an interviewed boat trip being counted by an aerial survey (Figure 2). Based on these rules, each interviewed boat trip for day d was assigned a binary indicator variable denoting if it was available to be counted on flight c. Based on these binary indicators, the following quantities were calculated:

- The number of interviewed trips available to be counted on flight c ($B_{c,d}$)
- The number of interviewed trips available to be counted on two consecutive flights c and c+1 ($B_{c,c+1,d}$)
- The number of interviewed trips available to be counted during at least one flight ($B_{y,d}$)
- The number of interviewed trips that were not available to be counted during at least one flight ($B_{n,d}$)

Based on these quantities, the effort expansion method corrected each aerial count by how many trips were also counted on the previous flight of the day by first calculating the proportion of known boat-trips counted on flight c+1 that were also counted on flight c ($p_{old,c}$):

$$p_{old,c,d}=\frac{B_{c,c+1,d}}{B_{c+1,d}}$$

The number of boats counted on flight c+1 that were not counted on flight c was:

$$\hat{A}_{c+1,d}=A_{c+1,d}(1-p_{old,c,d})$$

Note that this correction only needed to be conducted for c = 2 and c = 3, as $B_{1,d}$ were new entries to the fishery that day (i.e., the first flight was the first time they were counted). Then, the total number of boat trips accounted for that day was calculated as:

$$\widehat{E1}_d=A_{1,d}+\hat{A}_{2,d}+\hat{A}_{3,d}$$

To correct the count for trips that occurred between flights ($B_{n,d}$), a simple scaling method (similar to the Peterson estimator, Seber 1982) was applied and the result was added to $\widehat{E1}_d$:

$$\widehat{E2}_d=B_{n,d}\left(\frac{\widehat{E1}_d}{B_{y,d}}\right)+\widehat{E1}_d$$

To arrive at a total effort estimate for day d ($\hat{E}_d$), the average of $\widehat{E1}_d$ and $\widehat{E2}_d$ was used. Through simulation, we have shown that the estimator $\widehat{E1}_d$ is biased low due to trips both beginning and ending during times not flown and the estimator $\widehat{E2}_d$ is biased high, the severity of which depends on the relative availability to be counted of those boats returning to the Bethel boat harbor versus those returning to other locations (i.e., belonging to fishers not living in Bethel). Taking the average of the two estimators was intended to minimize biases likely induced by non-representative sampling. $\hat{E}_d$ was post-stratified into geographic strata based on the average proportion of boats counted in each stratum each day:

$$p_{j,d}=\frac{\sum_c B_{c,j,d}}{\sum_c \sum_j B_{c,j,d}}$$

$$\hat{E}_{j,d}=p_{j,d}\hat{E}_d$$

Set Net Effort Expansion Model

Due to a severe lack of interviews from set net fishers, the procedure described above for drift boat fishers was not possible. To account for daily set net effort, the maximum set net aerial count from each day was used as the effort for that day.

Harvest Expansion Model

The harvest expansion model used the two pieces of information (catch rates from trip interviews and total effort estimates) to estimate the total harvest by geographic stratum and day. First, trip-level effort was calculated:

$$e_{i,j,d}=L_{i,j,d}h_{i,j,d}$$

where one unit of effort was quantified as one foot of net soaked for one hour to account for different fishers using different lengths of net. Then, catch-per-unit-effort (CPUE) was calculated for each species to standardize catch numbers across trips:

$$CPUE_{s,i,j,d}=\frac{C_{s,i,j,d}}{e_{i,j,d}}$$

The quantities $L_{i,j,d}$, $h_{i,j,d}$ and $CPUE_{s,i,j,d}$ were averaged across interviews by geographic and temporal strata to estimate the quantities associated with a typical trip ($\hat{L}_{j,d}$, $\hat{h}_{j,d}$and $\widehat{CPUE}_{s,j,d}$). Total harvest of species *s* for stratum *j* on day *d* was calculated as:

$$\hat{H}_{s,j,d}=\hat{E}_{j,d}\hat{L}_{j,d}\hat{h}_{j,d}\widehat{CPUE}_{s,j,d}$$

This expansion was conducted separately for drift net fishers and set net fishers, using only the interviews from each gear type.

This expansion was done as geographically-explicit as possible. However, some strata were chronically lacking in interview data, which required that interview data from neighboring strata be used in these cases. Strata A, B, and C typically had enough information to perform the expansion separately, whereas strata D and E required interview information from the other strata. This is a result of the sampling design where interviews were conducted predominantly in the Bethel area.

Uncertainty Estimation

Variation in between-interview quantities (e.g., $h_{i,j,d}$, $L_{i,j,d}$, and $CPUE_{s,i,j,d}$) was included in the analysis using non-parametric bootstrapping. Bootstrapping involves randomly sampling (with replacement) from the observed trip interviews, producing a harvest expansion estimate following the above method for each randomized data set, and repeating the process thousands of times to form a distribution of possible harvests. First, *n* interviews were sampled from the pool of interviews for that temporal and geographic stratum, where *n* is the number of interviews collected for that temporal and geographic stratum. Then, the quantities $\hat{L}_{j,d}$, $\hat{h}_{j,d}$and $\widehat{CPUE}_{s,j,d}$ were calculated from the resampled data set and were multiplied by $\hat{E}_{j,d}$. To summarize the resulting variation, the 2.5th and 97.5th percentiles were used as the lower and upper bounds, respectively, and the mean of all estimates was used as the point estimate.

While there are other methods to estimate uncertainty in the harvest estimates, it was determined that the non-parametric bootstrap was the most appropriate method because other methods make a variety of tenuous assumptions. It is important to recognize that the harvest estimates contained in this report do not account for error in the process of estimating effort (i.e., boat trips) during aerial surveys. Thus, uncertainty in the harvest estimates is smaller than if uncertainty in effort was fully considered.

Computation

All analyses were conducted in the statistical programming environment R using custom code. During the season, summary documents were produced using RMarkdown.

RESULTS

First Opener (6/12/2016)

We estimated that a total of 542 boat trips occurred within the YDNWR on June 12 during the 12 hour opener (Table 3). The mean estimated total salmon harvest was 5,290 (95% CI: 4,340 - 6,420). Most of this harvest was Chinook salmon (4,460; 3,620 – 5,480), followed by chum (610; 440 – 830) and sockeye (220; 140 – 310) (Table 4, Figure 3). Most of this harvest came from geographic strata A and B, as that is where the majority of boats were fishing (Tables 3 and 4). These estimates were produced from 136 completed trip interviews, of which 107 came from the Bethel boat harbor and 29 came from the villages of Kalskag and Aniak. There were insufficient set net interviews (n = 1)

to expand on, so set net harvest was ignored for this opener and no fish camp interviews were available. Based on the distribution of relevant interview quantities from the first opener (Figure 4), it was clear that most fisher trips began in the early afternoon, lasted between 1 and 6 hours, and most nets soaked for between 1 and 3 hours. Very few fishers caught more than 20 total salmon and more than 10 Chinook salmon. Overall, very few chum and sockeye were caught, as evident from an average chum/sockeye to Chinook ratio of 0.3. On June 12, the Bethel test fishery chum/sockeye to Chinook ratio was 0.0, as no chum or sockeye were caught in the index fishery.

Second Opener (6/16/2016 – 6/17/2016)

We estimated that a total of 646 and 216 boat trips occurred within the YDNWR on June 16 and June 17 during the 24 hour opener, respectively (Table 3). The mean estimated total salmon harvest was 13,696 (95% CI: 11,010 – 16,908), with the majority of harvest on June 16 (82%). Most of this harvest was Chinook salmon (8,481; 7,000 – 10,175), followed by chum (3,225; 2,317 – 4,360) and sockeye (1,990; 1,225 – 3,126) (Tables 5 and 6, Figure 3). Of this harvest, over 96% was from drift net fishers. We estimated a total of 17 and 11 set nets were fishing on June 16 and June 17, and harvested 427 (93 – 969) total salmon. The majority of set nets were placed in stratum C (between Napaskiak and Akiachak). Much of the harvest from both days came from geographic strata A, B, and C (spanning Eek Island to Akiachak) and comparatively little harvest came from stratum E (upstream of Kalskag). These estimates were produced from 149 completed trip interviews, of which 122 came from the Bethel boat harbor and 27 came from Bethel area fish camps. There were nine completed interviews from set net fishers, although there was not enough geographic resolution to stratify by area (Table 6). Based on the distribution of relevant interview quantities from the second opener (Figure 5), it was clear that most fisher trips started between 10:00 am and 3:00 pm, lasted between 1 and 6 hours, and most nets soaked for between 1 and 3 hours. Very few fishers caught more than 30 total salmon and more than 20 Chinook salmon. Comparing fisher types, fish camp fishers harvested more total salmon per trip (mean 17.8 versus 11.2 for boat ramp fishers), nearly twice as many Chinook salmon (mean 13.5 versus 7.4 for boat ramp fishers), had nearly equal tri p lengths (mean 4.7 hours versus 4.3 hours for boat ramp fishers), but spent more of their time actively fishing (mean 5.5 soak hours versus 3 soak hours for boat ramp fishers) (Figure 5). In comparison to Chinook salmon, few chum and sockeye were caught, as evident from an average chum/sockeye to Chinook ratio of 0.6. Set nets had a slightly lower species ratio than drift nets (mean 0.44 versus 0.64), which is counter-intuitive given that set netters used smaller mesh on average than drift netters (5.2 inches versus 5.9 inches). On June 16 and June 17, the Bethel test fishery chum/sockeye to Chinook ratio was 0.7 and 0.2, respectively.

Third Opener (6/21/2016 – 6/24/2016)

We estimated that a total of 555, 334, 245, and 49 boat trips occurred within the YDNWR on June 21, June 22, June 23, and June 24 during the 72 hour opener, respectively (Table 3). The mean estimated total salmon harvest was 39,860 (95% CI: 32,330 – 48,665), with the majority of harvest on 6/21/2016 (53%). Most of this harvest was chum salmon (15,971; 12,141 – 20,826), followed by Chinook (13,130; 10,276 – 16,506) and sockeye (10,759; 7,801 – 14,436) (Tables 7 and 8, Figure 3). Of this harvest, over 91% was from drift net fishers. We estimated a total of 36, 21, 23, and 23 set nets were fishing on June 21, June 22, June 23, and June 24, respectively, and harvested a total of 3,323 (1,374 – 5,775) salmon. The majority of set nets were placed in stratum C (between Napaskiak and Akiachak; Table 2). Much of the harvest during the third opener came from geographic strata A, B, and C (spanning Eek Island to Akiachak) and comparatively little harvest came from stratum E (upstream of Kalskag). These estimates were produced from 202 completed trip interviews, of which 166 came from the Bethel boat harbor and 36 came from Bethel area fish camps. There were 12 completed interviews from set net fishers, although there was not enough geographic resolution to stratify

by area (Table 8). Based on the distribution of relevant interview quantities from the third opener (Figure 6), it was clear that most fisher trips started between 10:00 am and 8:00 pm, lasted between 1 and 6 hours, and most nets soaked for between 1 and 3 hours. Very few fishers caught more than 40 total salmon and more than 15 Chinook salmon. Comparing fisher types, fish camp fishers harvested more total salmon per trip (mean 25.7 versus 18.1 for boat ramp fishers), more Chinook salmon (mean 10.5 versus 6.3 for boat ramp fishers), and had nearly equal trip lengths as boat ramp fishers (mean 2.8 hours versus 3.0 hours for boat ramp fishers) (Figure 6). On average, the sum of chum and sockeye salmon catch was greater than Chinook, as evident from an average chum/sockeye to Chinook ratio of 2.9. Set nets had a slightly lower species ratio than drift nets (mean 2.7 versus 2.9), which is counter-intuitive given that set netters used smaller mesh on average than drift netters (4.9 inches versus 5.7 inches). On June 21, June 22, June 23, and June 24 the Bethel test fishery chum/sockeye to Chinook ratio was 6.4, 1.7, 5.3, and 4.1, respectively.

Fourth Opener (6/29/2016 – 7/2/2016)

We estimated that a total of 195, 167, 207, and 30 boat trips occurred within the YDNWR on June 29, June 30, July 1, and July 2 during the 72 hour opener, respectively (Table 3). The mean estimated total salmon harvest was 21,590 (95% CI: 13,639 – 33,641), with this harvest being split fairly equally between the first three days (35%, 28%, and 31% on June 29, June 30, and July 1, respectively). Most of this harvest was sockeye salmon (12,051; 7,450 – 18,816), followed by chum (7,592; 4,123 – 12,886) and Chinook (1,948; 1,297 – 2,751) (Tables 9 and 10, Figure 3). Of this harvest, 85% was from drift net fishers. We estimated a total of 9, 17, 8, and 4 set nets were fishing on June 29, June 30, July 1, and July 2, respectively, and harvested a total of 3,248 (718– 9,002) salmon. These estimates were produced from 125 completed trip interviews, of which 114 came from the Bethel boat harbor and 11 came from Bethel area fish camps. There were 11 completed interviews from set net fishers, although there was not enough geographic resolution to stratify by area (Table 10). Based on the distribution of relevant interview quantities from the fourth opener (Figure 7), it was clear that most fisher trips started between 10:00 am and 8:00 pm, lasted between 1 and 5 hours, and most nets soaked for between 1 and 3 hours. Very few fishers caught more than 50 total salmon and more than 5 Chinook salmon. Comparing fisher types, fish camp fishers harvested more total salmon per trip (mean 26.7 versus 20.2 for boat ramp fishers), equal numbers of Chinook salmon (mean 2.1 versus 2.2 for boat ramp fishers), and had equal trip lengths as boat ramp fishers (mean 2.2 hours versus 2.2 hours for boat ramp fishers) (Figure 6). On average, the sum of chum and sockeye salmon catch was greater than Chinook, as evident from an average chum/sockeye to Chinook ratio of 9.3 (fish camp mean = 15.6; boat ramp mean = 9.5). Unlike the second and third openers, set net fishers during the fourth opener had a higher species ratio than drift nets (mean 13 versus 9.9). On June 29, June 30, July 1, and July 2, the Bethel test fishery chum/sockeye to Chinook ratio was 6.8 and 10.1, 16.4, and 12.5, respectively.

Total Harvest across All Openers

Across all openers, we estimated that a total of 80,443 (49,883 – 122,070) salmon were harvested. Of this, most was Chinook (28,019; 18,878 – 39,774), followed closely by chum (27,398; 16,157 – 43,146), and sockeye (25,026; 14,848 – 39,150) (Table 11, Figure 8). Fishers within geographic stratum C (Napaskiak to Akiachak) harvested the most total salmon (29,232; 17,881 – 44,984), made up primarily of chum salmon (11,848; 6,788 – 19,052), while stratum A (below Johnson River) harvested the most Chinook salmon (9,225; 5,919 – 13,508) (Table 11; Figure 9). Stratum E harvested a very small portion of the total salmon harvest (3%; 2,292; 1,699 – 3,092) (Table 11, Figure 9). In general, there was a decreasing trend through time in the estimated number of boat trips (Figure 10), although in the second and third openers there was an increase in effort on the first day.

DISCUSSION

The analyses presented within this document represent the first directed efforts at rigorously estimating in-season salmon harvest in the Kuskokwim River subsistence fishery. These estimates and the associated information (e.g., number of drift boats, total salmon catch per boat, and species ratios) proved to be invaluable to the decision-making process in the 2016 season. Additionally, stakeholders who were not actively involved in the decision-making process, such as the KRSMWG members, were interested in learning how many fish had been harvested to date. Information gleaned from this analysis not only provided critical harvest estimates, but also has contributed substantially to the understanding of the behavior of the fishery. For example, because aerial surveys were flown so often, it was possible to precisely monitor the decline in effort as the season progressed. This information is historically-available in some form post-season, though at that point it is no longer useful to in-season management.

Due to the value of the harvest estimates and the corresponding information to in-season management, we suggest that in-season harvest estimates be produced in years where a block-opener management tactic is implemented to meet a harvest objective. In order to make the decision to have another opener (and how long to make it), managers needed to know how much harvest to anticipate in the proposed opener and how much harvest had been taken to date. Without this information, the decision becomes much less informed and is thus subject to substantial pitfalls (e.g., optimism). However, in years of higher abundance where meeting the escapement goal is of less concern, a block-opening management structure is not likely necessary as the subsistence fishery may not be able to harvest enough fish to prevent the escapement goal from being met. In these cases, it could be argued that estimates of in-season harvest have little value as there would be no active management decisions to be made based on them.

Despite the utility of the information gained in the harvest estimation process, it came at a substantial cost in terms of both fiscal and personnel resources. Each aerial survey flight cost an estimated $750 in aircraft expenditures and required a YDNWR pilot and at least one observer. Additionally, substantial time was spent by ONC personnel conducting the completed trip interviews, which is a project they are not currently funded for (Greg Roczicka, pers. comm.). Oftentimes, this involved upwards of 40 man hours per day on the part of ONC (3 – 4 interviewers for 10+ hours per day). Besides the data collection efforts, substantial time was spent in the analysis of the data, including data entry, writing custom code, and preparing summary documents. After an opener, an estimated 20 man hours were spent in producing the harvest estimates (1-2 analysts over 1-2 days). However, because so much time was invested in 2016, the analysis framework is now in place and should require less time in the future.

As previously mentioned, the analyses presented in this document ubiquitously made the assumption that the interview information was a random sample from the population of fishers during the opener. This assumption is not unique to these analyses, or even creel surveys in general, but is made in every statistical analysis where samples are used to make inference on a population. It cannot be overemphasized that the sampling design for the 2016 completed trip interviews was not implemented in a random sense, but could be much more accurately described as opportunistic. Interviews came nearly exclusively from the Bethel area, which brings to question the representation of these data of the fishers spanning the entire YDNWR. There are ways to obtain interviews from other areas in the YDNWR without actively sending personnel there in-season. For example, USFWS could train a subset of fishers from each village to gather this information from their village and report the information back in a timely manner. The KRITFC could be involved in this process and this type of collaboration would increase resource user involvement in the management of the fishery, and this is generally seen as advantageous (Greg Roczicka, pers. comm.).

Some efforts to organize a program like this are underway, and we suggest that these options be explored in future years to add to the accuracy and defensibility of the resulting estimates.

Furthermore, because the majority of interviews were conducted at the Bethel boat harbor, the interviews used in this analysis were likely not even representative of the population of Bethel area fishers. Fishers returning to the Bethel boat harbor have a tendency to harvest fewer fish than users occupying fish camps, which was further elucidated in this study by comparing interview quantities between the boat harbor and fish camps. Due to the nature of the sampling design, we do not believe that fish camps were sampled in proportion to their prevalence in the Bethel area. To account for this discrepancy, ideally there would be another stratum for fisher type: fish camp versus boat harbor. This was not possible in this analysis, however, because total boat trip estimates were not separable by fisher type (i.e., when boats were counted via aerial survey, it was impossible to determine if each boat was a fish camp fisher or a boat ramp fisher). This remains an area for future improvement to the study design. Stratification by fisher type would not be necessary if each type were interviewed in proportion to its relative abundance in the fishery, and thus we suggest that future efforts focus on designing the interview sampling in a more representative manner, rather than developing an ad-hoc method for accounting for the discrepancy in sampling. It should be noted that neither was attempted in the 2016 design.

Another source of potential bias was in the drift boat effort expansion. We assumed that the trip times (i.e., T_1 and T_2) were representative of the population of YDNWR fisher trips, however this was likely not the case. Bethel area fishers may have been more likely to fish later in the day to coincide with their work schedule, which may not have been the case for other villages. Additionally, near villages with fewer adequate drift locations than those present in the Bethel area (e.g., Kalskag, Greg Roczicka, pers. comm.), fishers may have been required to fish for longer periods of time (which could cause biases in the effort expansion). If village-specific interviews were available, these issues could be accounted for by producing stratified boat expansions based on the counts made in each strata and the trip times from villages in each strata. While this certainly remains an area for future improvement, conducting the analysis in 2016 without this information did shed light on this clear data gap.

The issues of non-randomness described previously bring into question the accuracy of the resulting harvest. If the information we obtained was systematically biased (i.e., fishers upstream of Bethel fished longer, had higher catch rates, etc.), then the resulting estimates were also biased. We attempted to account for this in several ways. First, although we treated the information as though it was random, each time harvest estimates were presented to stakeholders and decision-makers, we made sure to make them fully aware of the limitations and problems with the analyses. Second, we produced estimates of uncertainty and emphasized that the estimates be interpreted in the full context of their uncertainty. To embrace this level of uncertainty, all decisions were made by considering both a “most likely” and a “worst case” scenario, using the point estimate and the upper bound of the estimates, respectively. We believe our work represents reasonable early steps towards structuring in-season harvest estimation during block openers, and that this approach is likely to improve as interested parties recognize the value of in-season harvest estimates and the necessary information required to produce valid and robust estimates.

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We would like to thank ONC for conducting the completed trip interviews, without which this analysis would not have been possible. In particular, we would like to thank Greg Roczicka and Janessa Esquible for their extensive time spent interviewing at the Bethel boat harbor, developing schedules, and providing the collected data in an extremely timely manner. Additionally, we would like to thank LaMont Albertson (KRITFC) for volunteering his time conducting interviews and serving as one of the primary voices

emphasizing the importance of in-season harvest estimates throughout the community. We would like to thank the Alaska Department of Fish and Game Kuskokwim Area Fishery Biologists, Zachary Liller and Nicholas Smith, for input on the effort expansion model. Gary Decossas, a biometrician with the USFWS Office of Subsistence Management, for providing input on the effort expansion and suggesting the geographic stratification of harvest expansions. We thank USFWS pilots: Robert Sundown, Mike Wade, Rory Stark, Dave Rippeto, and Nate Olsen for their time flying aerial effort surveys, and Aaron Moses (YDNWR Fisheries Biologist) for serving as the observer on many aerial effort surveys. Finally, we thank Aaron Webber and Bill Bechtol for review and subsequent improvements on an earlier draft of this report. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

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Figure 1. Map of the Yukon Delta National Wildlife Refuge waters with geographic strata noted (A – E). Solid points indicate strata boundaries.

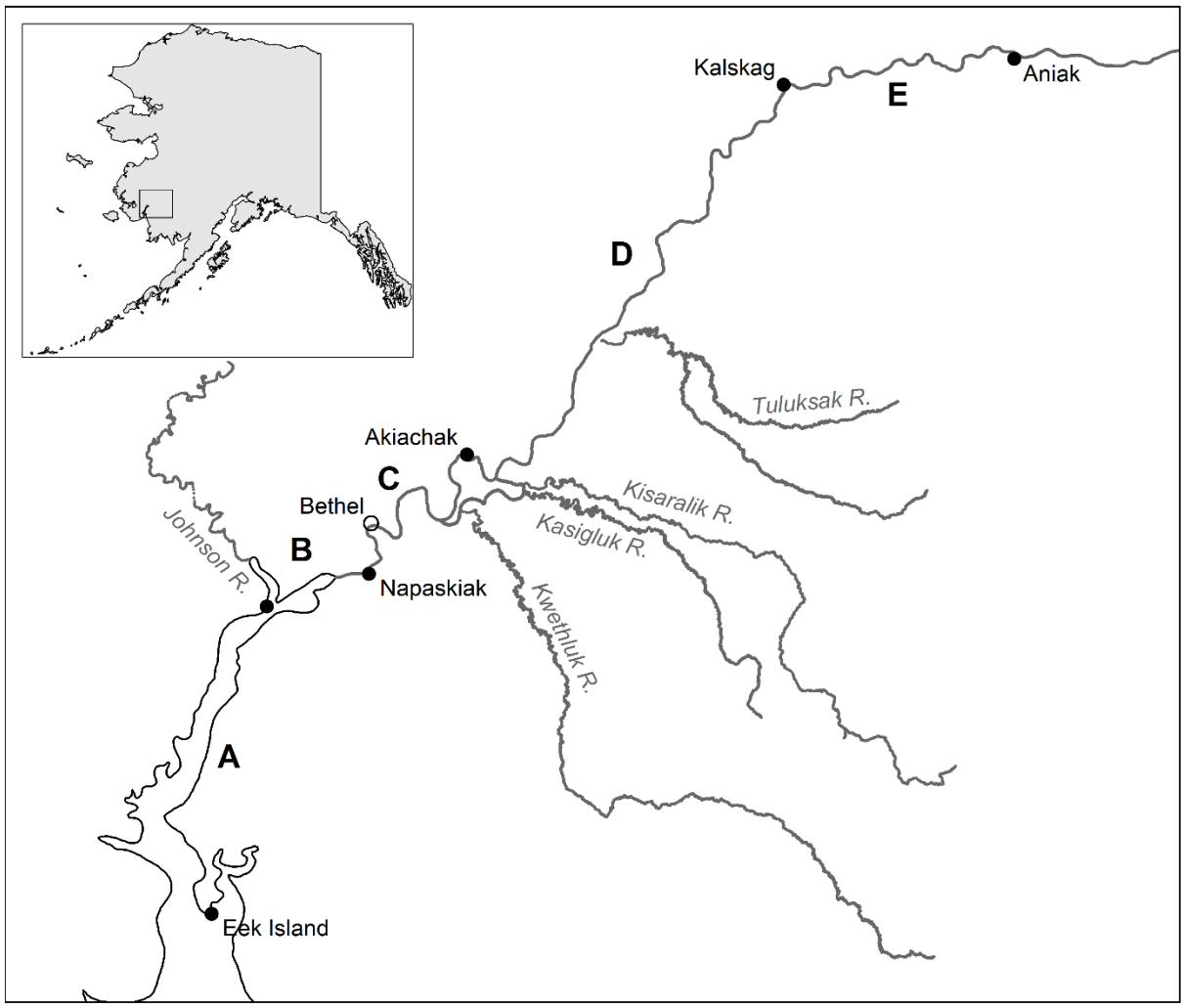

Figure 2. Illustration of the four possible scenarios that could lead to an interviewed trip being counted during an aerial flight.

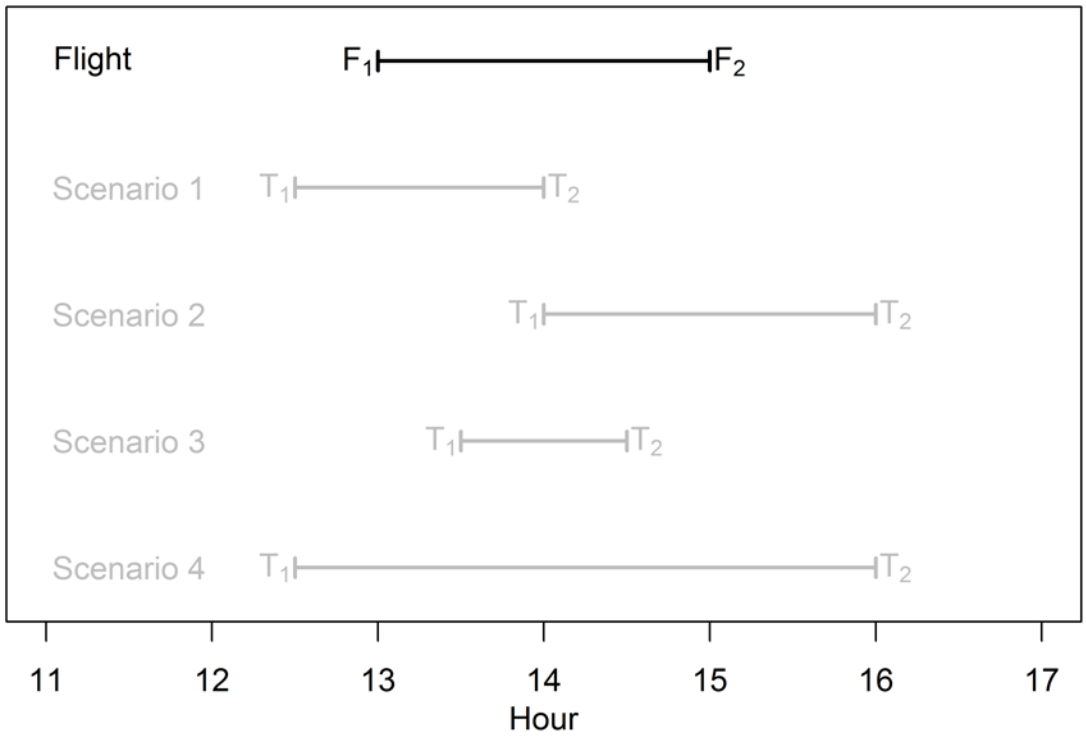

Figure 3. Estimated salmon harvest by species in each of the four openers.

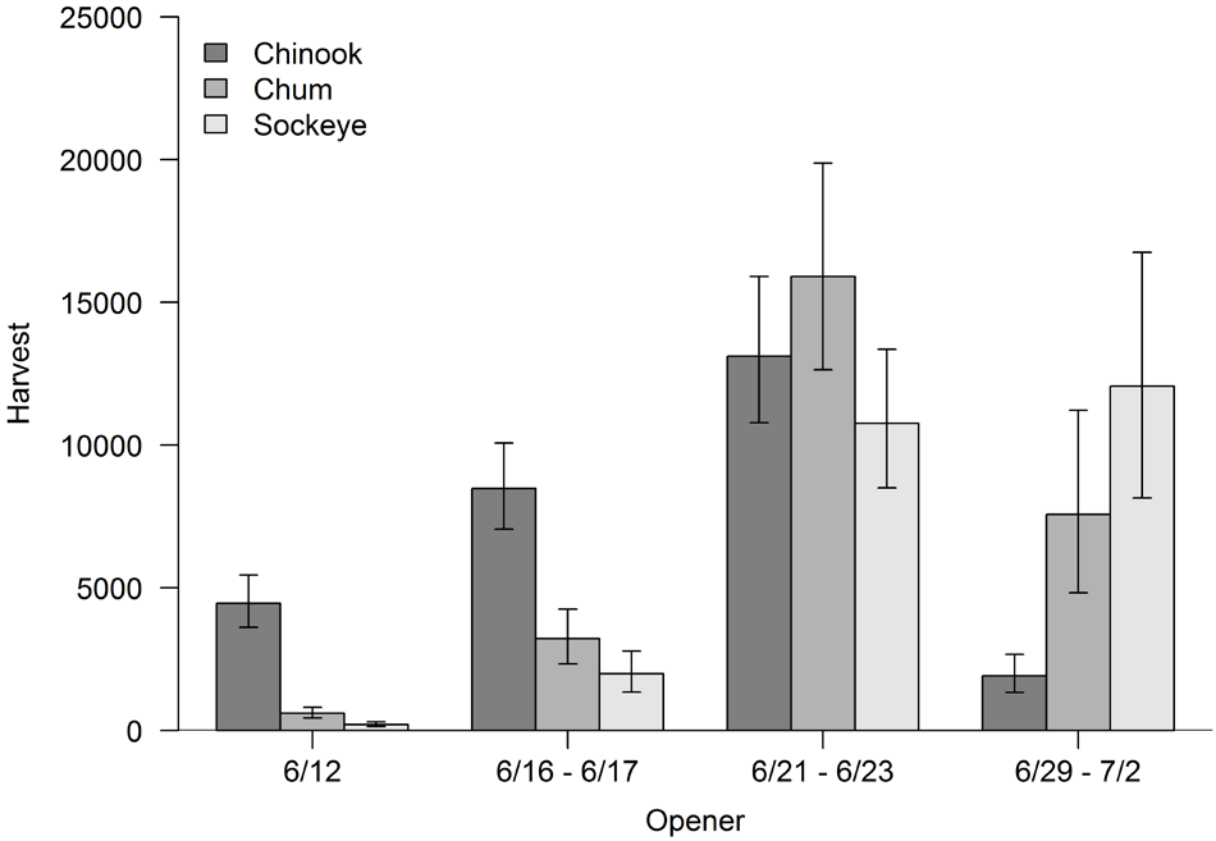

Figure 4. Distribution of relevant quantities from completed trip interviews (drift boat trips only) from the first opener (6/12/2016).

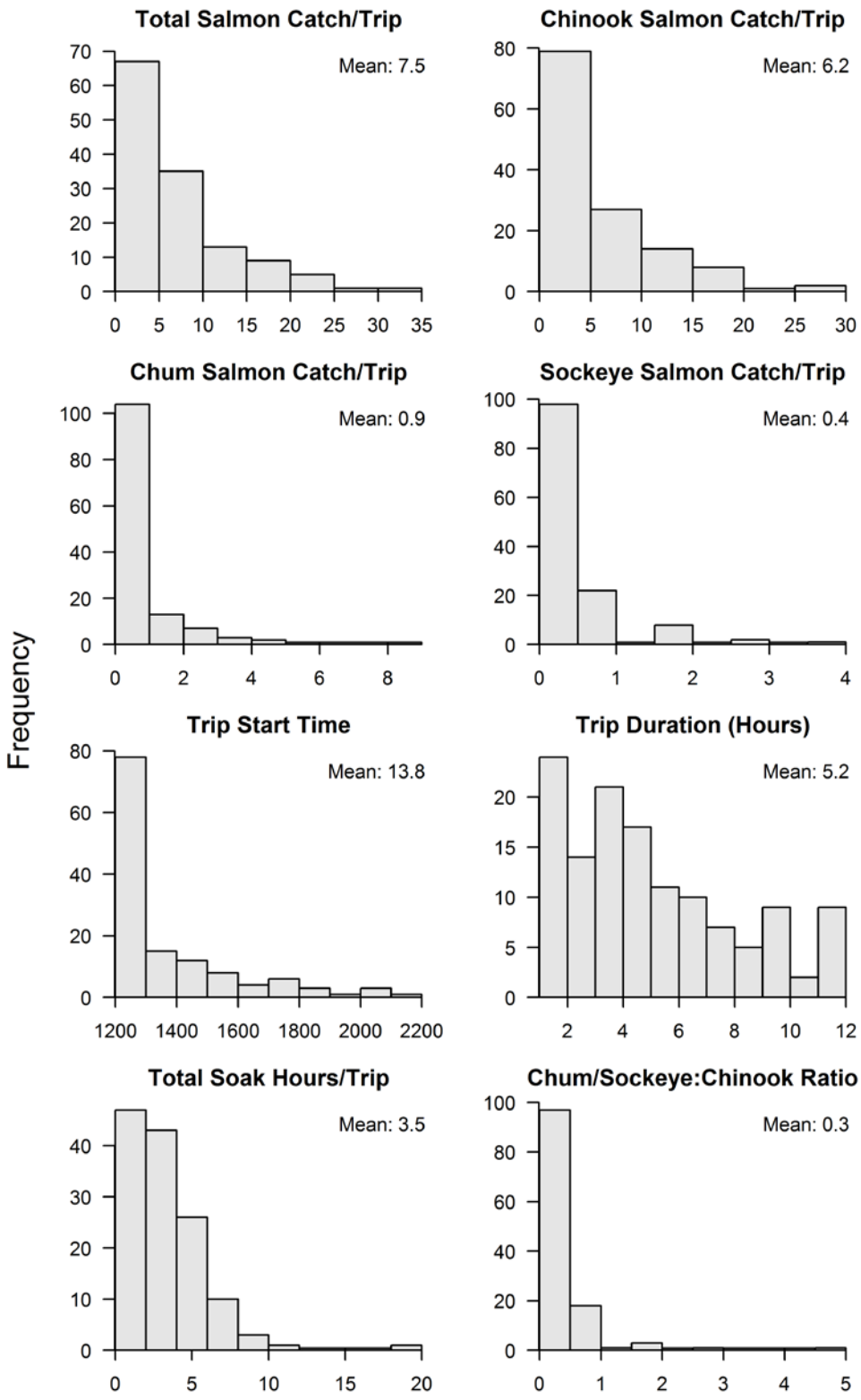

Figure 5. Distribution of relevant quantities from completed trip interviews (drift boat trips only) from the second opener (6/16/2016 – 6/17/2016) with means listed for the aggregate samples, boat ramp samples, and fish camp samples.

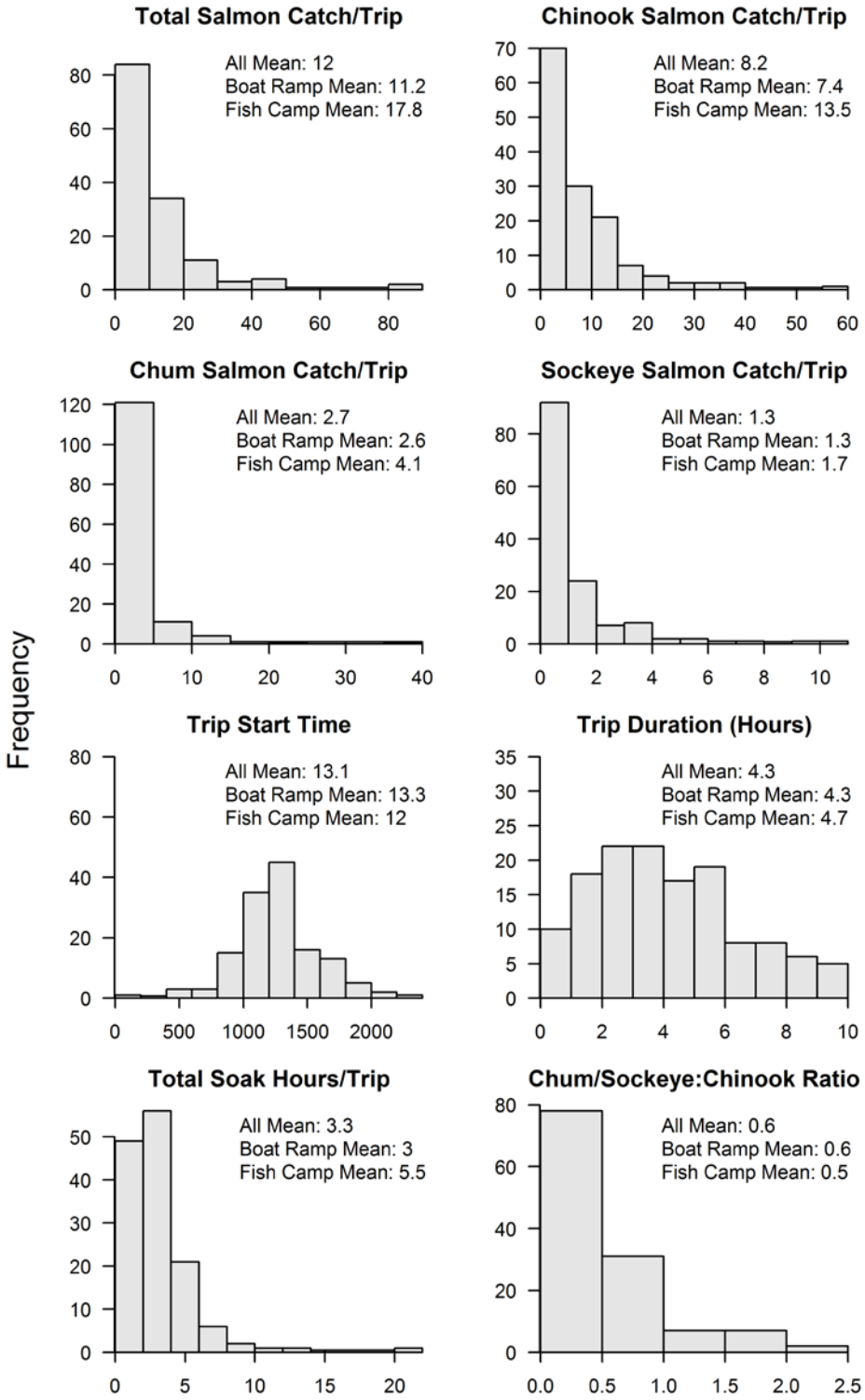

Figure 6. Distribution of relevant quantities from completed trip interviews (drift boat trips only) from the third opener (6/21/2016 – 6/24/2016) with means listed for the aggregate samples, boat ramp samples, and fish camp samples.

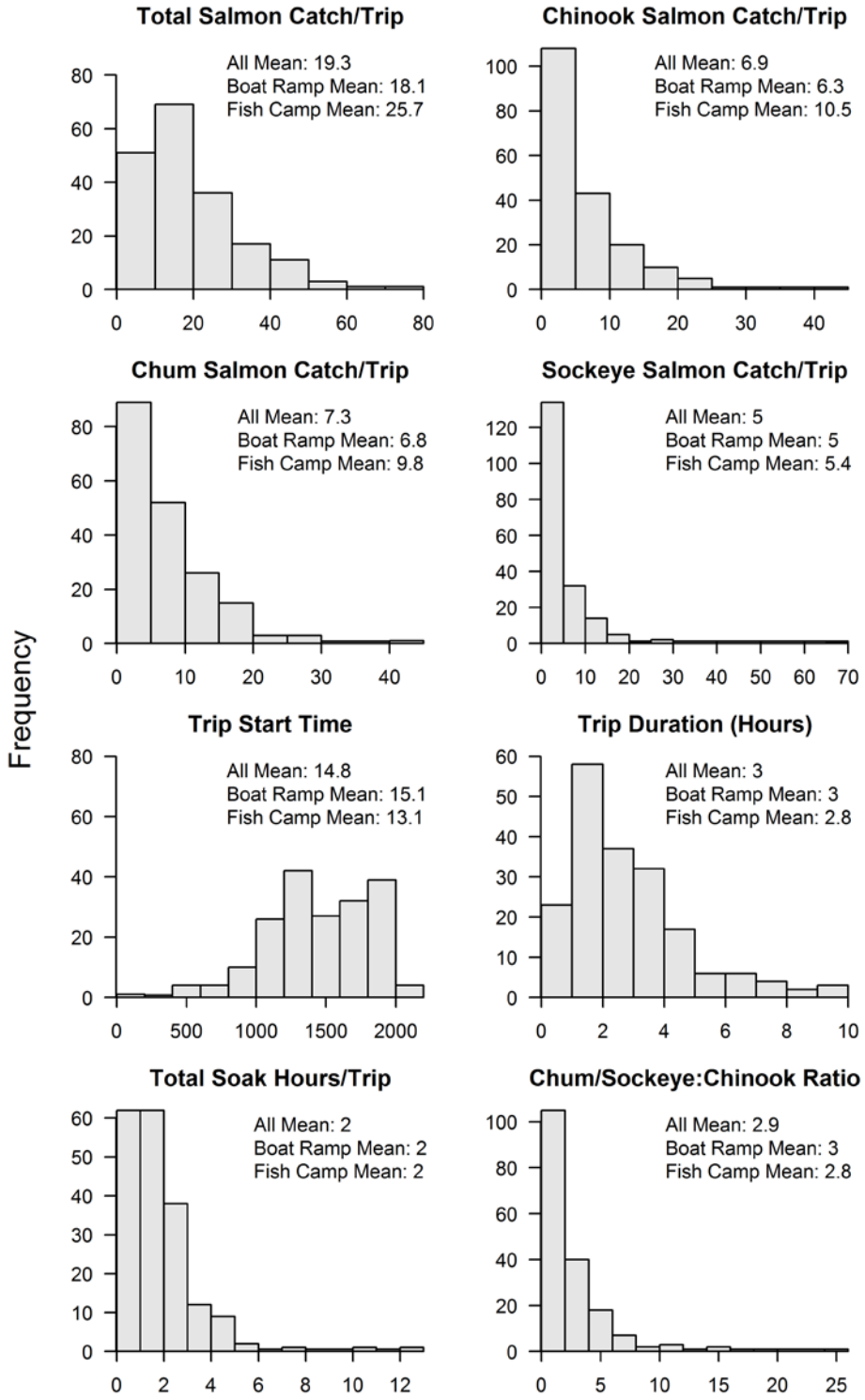

Figure 7. Distribution of relevant quantities from completed trip interviews (drift boat trips only) from the fourth opener (6/29/2016 – 7/2/2016) with means listed for the aggregate samples, boat ramp samples, and fish camp samples.

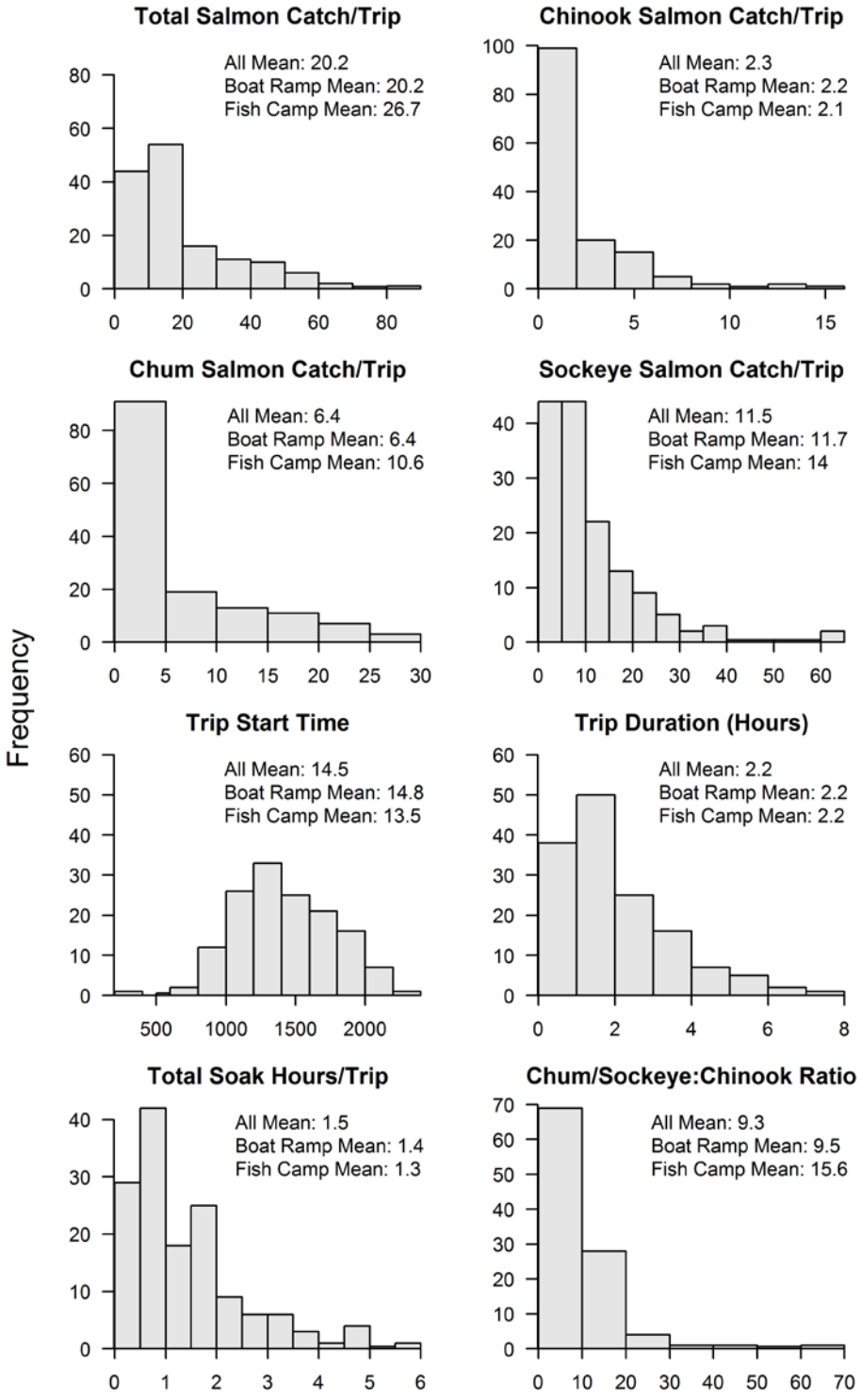

Figure 8. Total salmon harvest by species across all four openers. Includes harvest by both drift boat trips and set nets.

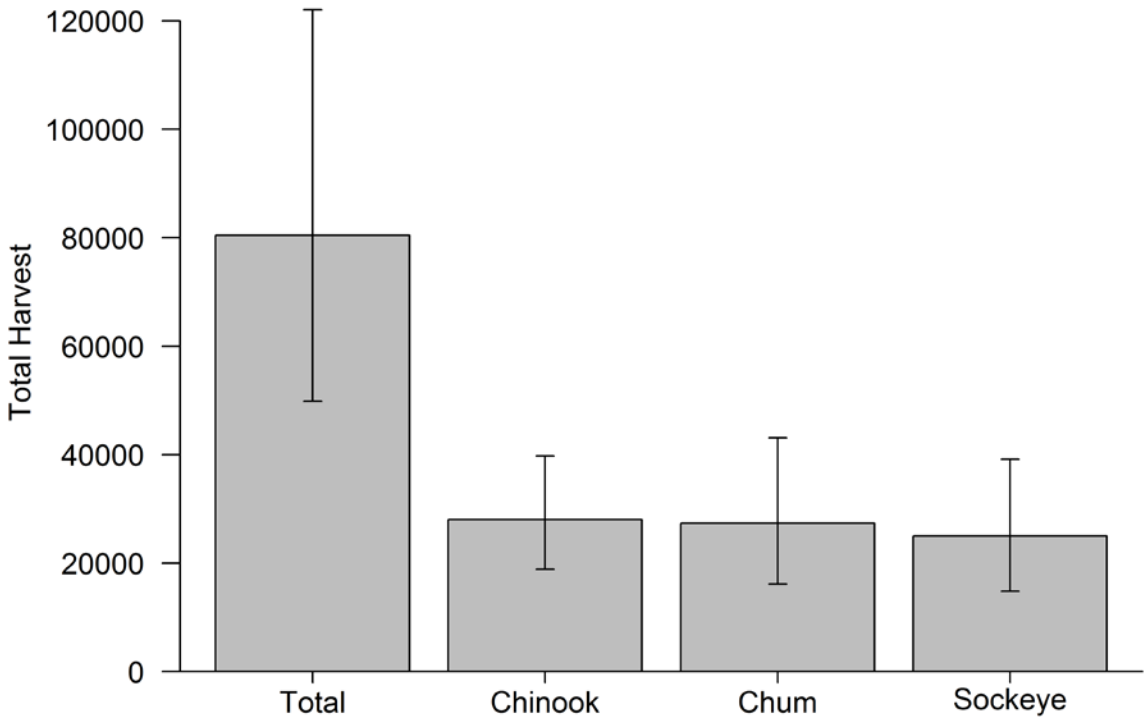

Figure 9. Total estimated salmon harvest by species and geographic stratum across all four openers. Includes harvest by both drift boat trips and set nets.

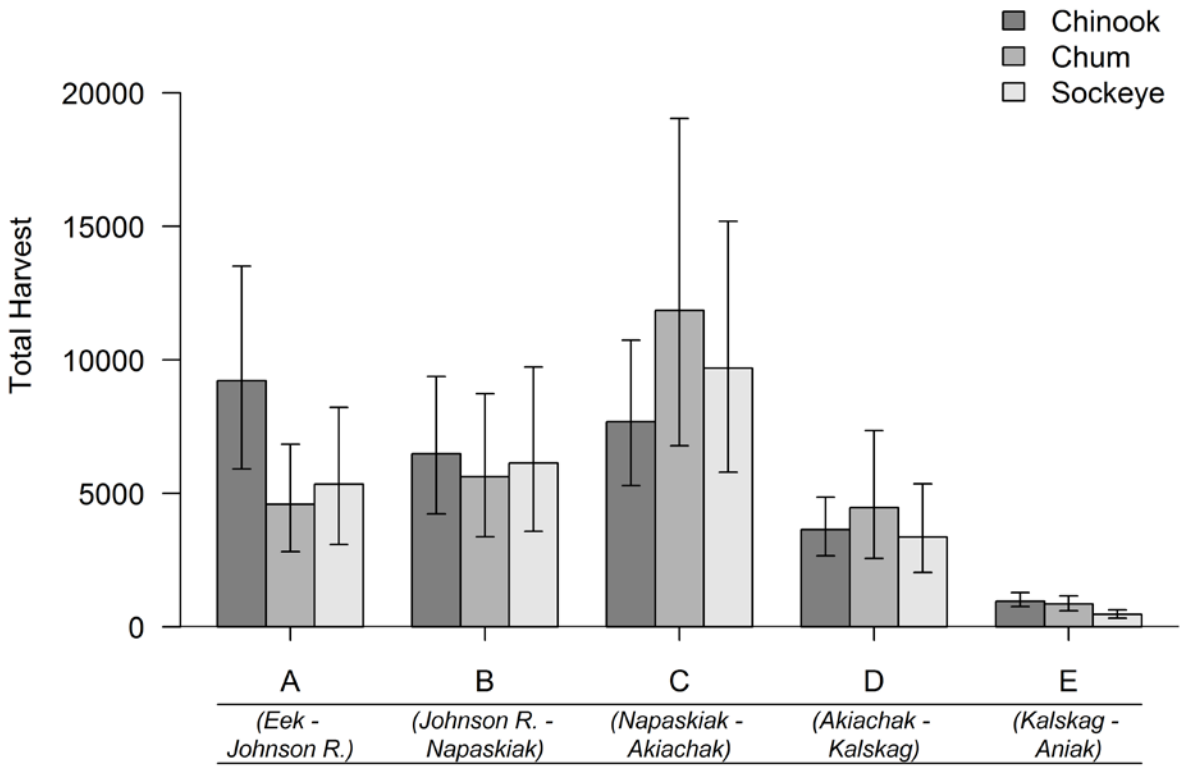

Figure 10. Total estimated drift boat trips by day, with openers indicated.

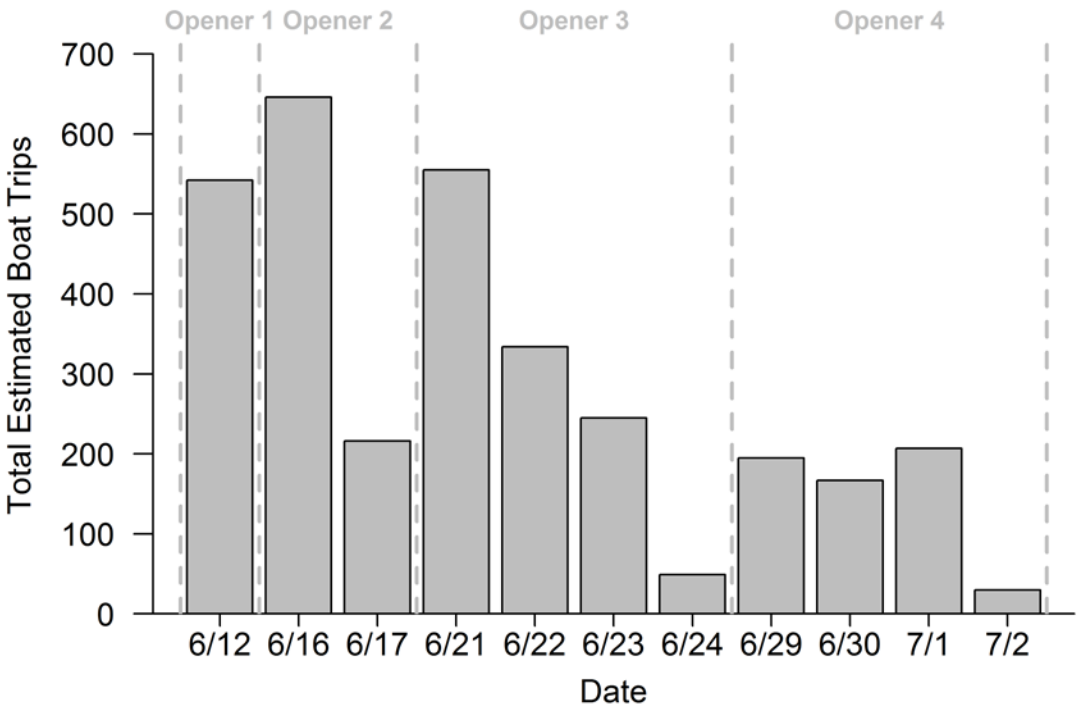

Table 1. Raw boat counts ($A_{c,j,d}$) from each flight and geographic stratum[3].

Opener	Date	Flight Times		Geographic Stratum					Total
		F_1	F_2	A	B	C	D	E	
1	6/12/2016	15:30	17:50	158	87	112	59	14	430
1	6/12/2016	20:30	22:00	126	91	93	65	14	389
2	6/16/2016	13:10	14:50	126	93	149	75	15	458
2	6/16/2016	20:05	21:40	79	46	93	59	8	285
2	6/17/2016	10:15	11:40	61	38	55	35	8	197
3	6/21/2016	15:10	17:10	140	79	107	51	6	383
3	6/21/2016	21:00	22:50	23	23	53	22	5	126
3	6/22/2016	10:40	12:40	10	13	18	6	1	48
3	6/22/2016	16:00	18:30	21	48	72	33	10	184
3	6/22/2016	21:06	23:00	3	11	33	7	6	60
3	6/23/2016	10:00	11:15	0	14	18	8	4	44
3	6/23/2016	17:00	18:10	27	33	48	10	10	128
3	6/23/2016[1]	21:30	—	3	11	33	7	6	60
3	6/24/2016[1]	9:00	—	0	14	18	8	4	44
4	6/29/2016	15:00	17:20	25	43	45	25	2	140
4	6/29/2016	21:40	23:40	13	8	31	10	0	62
4	6/30/2016	10:30	12:30	9	12	19	7	0	47
4	6/30/2016	16:00	18:10	9	17	29	6	1	62
4	7/1/2016	11:30	13:00	7	21	30	3	0	61
4	7/1/2016	17:00	18:20	12	18	45	12	0	87
4	7/2/2016[2]	10:30	11:30	0	0	24	4	0	28

[1] Could not conduct the flight due to inclement weather, used count from the same period on previous day
[2] No USFWS pilot was available, ADF&G law enforcement officer flew the flight
[3] Geographic strata: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiakchak to Kalskag, E = Kalskag to Aniak

Table 2. Set net counts from each flight and opener by geographic stratum[3]. The bolded total is the maximum count each day, which was used for set net harvest expansion.

Opener	Date	Flight Times		Geographic Stratum					Total
		F_1	F_2	A	B	C	D	E	
1	6/12/2016	15:30	17:50	0	0	11	6	0	17
1	6/12/2016	20:30	22:00	0	4	7	7	0	**18**
2	6/16/2016	13:10	14:50	2	1	13	1	0	**17**
2	6/16/2016	20:05	21:40	0	1	6	0	0	7
2	6/17/2016	10:15	11:40	0	2	8	1	0	**11**
3	6/21/2016	15:10	17:10	0	2	10	1	0	13
3	6/21/2016	21:00	22:50	0	5	26	4	1	**36**
3	6/22/2016	10:40	12:40	0	4	10	3	4	21
3	6/22/2016	16:00	18:30	0	2	12	3	0	17
3	6/22/2016	21:06	23:00	0	2	19	0	0	**21**
3	6/23/2016	10:00	11:15	0	1	17	5	0	**23**
3	6/23/2016	17:00	18:10	0	0	4	6	0	10
3	6/23/2016[1]	21:30	—	0	2	19	0	0	21
3	6/24/2016[1]	9:00	—	0	1	17	5	0	**23**
4	6/29/2016	15:00	17:20	0	2	4	3	0	**9**
4	6/29/2016	21:40	23:40	0	0	2	2	0	4
4	6/30/2016	10:30	12:30	0	5	7	5	0	**17**
4	6/30/2016	16:00	18:10	0	1	9	0	0	10
4	7/1/2016	11:30	13:00	1	1	4	2	0	**8**
4	7/1/2016	17:00	18:20	0	0	6	0	0	6
4	7/2/2016[2]	10:30	11:30	0	0	2	3	0	**5**

[1] Could not conduct the flight due to inclement weather, used count from the same period on previous day
[2] No USFWS pilot was available, ADF&G law enforcement officer flew the flight
[3] Geographic strata: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiakchak to Kalskag, E = Kalskag to Aniak

Table 3. Estimated drift boat trips by day and geographic stratum[1] ($\widehat{E}_{j,d}$). Duration is the number of hours the fishery was open that day.

Opener	Date	Duration	Geographic Stratum					Total
			A	B	C	D	E	
1	6/12/2016	12	188	118	136	82	18	542
2	6/16/2016	12	178	118	210	120	20	646
2	6/17/2016	12	67	42	60	38	9	216
3	6/21/2016	12	152	108	194	86	15	555
3	6/22/2016	24	41	80	146	47	20	334
3	6/23/2016	24	22	62	109	30	22	245
3	6/24/2016	12	0	16	20	9	4	49
4	6/29/2016	12	38	42	80	33	2	195
4	6/30/2016	24	28	44	73	20	2	167
4	7/1/2016	24	26	57	104	20	0	207
4	7/2/2016	12	0	0	26	4	0	30

[1] Geographic strata: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiakchak to Kalskag, E = Kalskag to Aniak

Table 4. Salmon harvest from the first opener (6/12/2016) by species and geographic strata[1].

Date	Species	Geographic Stratum					Total
		A	B	C	D	E	
6/12/2016	Chinook	1,746 (1,134-2,547)	1,207 (773-1,786)	763 (558-1,011)	576 (431-751)	170 (107-248)	4,460 (3,620-5,480)
	Chum	270 (126-463)	146 (76-239)	107 (62-162)	76 (50-108)	12 (5-21)	610 (440-830)
	Sockeye	62 (15-129)	79 (33-141)	38 (15-69)	33 (18-51)	3 (0-7)	220 (140-310)
	Total	2,078 (1,375-2,998)	1,432 (958-2,069)	908 (672-1,187)	685 (521-881)	185 (118-268)	5,290 (4,340-6,420)

[1] Geographic strata: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiakchak to Kalskag, E = Kalskag to Aniak

Table 5. Salmon harvest from drift boat trips during the second opener (6/16/2016 – 6/17/2016) by species and geographic strata[1].

Date	Species	Geographic Stratum					Total
		A	B	C	D	E	
6/16/2016	Chinook	3,410 (2,373-4,655)	1,420 (877-2,142)	1,113 (822-1,446)	824 (619-1073)	188 (120-274)	6,955 (5,671-8,404)
	Chum	1,352 (722-2,178)	517 (270-859)	348 (244-469)	272 (193-368)	13 (6-22)	2,501 (1,782-3,394)
	Sockeye	728 (355-1,262)	333 (172-546)	239 (163-328)	183 (128-249)	3 (0-7)	1,486 (1,049-2,057)
	Total	5,490 (3,802-7,511)	2,270 (1,410-3,412)	1,699 (1,296-2,158)	1278 (975-1,644)	204 (132-295)	10,942 (8,907-13,263)
6/17/2016	Chinook	529 (174-1,053)	269 (76-575)	327 (117-657)	228 (97-428)	87 (54-128)	1,439 (895-2,112)
	Chum	158 (27-399)	74 (9-209)	275 (35-724)	169 (27-437)	6 (3-10)	682 (253-1,239)
	Sockeye	114 (14-308)	69 (9-194)	8 (0-21)	15 (2-35)	2 (0-3)	207 (68-423)
	Total	801 (238-1,711)	412 (101-929)	609 (165-1,383)	412 (136-875)	94 (59-138)	2,329 (1,304-3,602)
Entire Opener	Chinook	3,940 (2,799-5,265)	1,689 (1,086-2,463)	1,441 (1,054-1,903)	1,050 (787-1,364)	275 (197-366)	8,395 (6,981-9,980)
	Chum	1,511 (855-2,367)	591 (328-961)	623 (326-1,079)	439 (251-723)	19 (11-29)	3,183 (2,317-4,219)
	Sockeye	841 (436-1,400)	402 (217-639)	247 (169-336)	197 (140-265)	5 (2-9)	1,692 (1,220-2,292)
	Total	6,292 (4,438-8,438)	2,682 (1,727-3,921)	2,312 (1,630-3,191)	1,686 (1,224-2,267)	298 (216-395)	13,271 (10,917-15,939)

[1] Geographic strata: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiakchak to Kalskag, E = Kalskag to Aniak

Table 6. Salmon harvest from the second opener (6/16/2016-6/17/2016) by set nets.

Day	Species	Harvest
6/16/2016	Chinook	52 (12-118)
	Chum	25 (0-86)
	Sockeye	181 (3-506)
	Total	259 (56-588)
6/17/2016	Chinook	34 (7-77)
	Chum	16 (0-55)
	Sockeye	117 (2-328)
	Total	168 (37-381)
Entire Opener	Chinook	86 (19-195)
	Chum	42 (0-141)
	Sockeye	298 (5-834)
	Total	427 (93-969)

Table 7. Salmon harvest from drift boat trips from the third opener (6/21/2016 – 6/24/2016) by species and geographic strata[1].

Date	Species	Geographic Stratum					Total
		A	B	C	D	E	
6/21/2016	Chinook	2,271 (968-4,217)	1,150 (720-1,694)	2,110 (1,315-3,282)	930 (633-1,336)	163 (110-236)	6,625 (4,841-8,885)
	Chum	1,328 (743-2,057)	957 (554-1,495)	4,470 (2,009-7,857)	1593 (826-2,690)	278 (142-471)	8,626 (5,840-12,189)
	Sockeye	1,960 (823-3,436)	716 (408-1,126)	916 (525-1,447)	460 (297-665)	80 (52-117)	4,132 (2,817-5,733)
	Total	5,559 (3,426-8,412)	2,823 (1,789-4,164)	7,496 (4,352-11,879)	2,984 (1,923-4,458)	522 (333-783)	19,383 (14,973-24,769)
6/22/2016	Chinook	615 (252-1,188)	1,219 (460-2,306)	867 (484-1,406)	402 (224-654)	167 (95-271)	3,270 (2,213-4,589)
	Chum	358 (190-579)	1,217 (468-2,302)	896 (502-1,442)	408 (230-652)	169 (97-267)	3,048 (2,087-4,294)
	Sockeye	526 (213-968)	1,019 (393-1,943)	599 (338-966)	303 (166-497)	126 (70-207)	2,573 (1,734-3,644)
	Total	1,498 (869-2,365)	3,455 (1,471-6,245)	2,362 (1,433-3,628)	1,113 (654-1,745)	462 (276-722)	8,890 (6,339-12,086)
6/23/2016	Chinook	323 (136-607)	533 (247-988)	643 (421-929)	194 (128-280)	140 (92-201)	1,833 (1,352-2,420)
	Chum	188 (103-298)	776 (308-1,458)	1,399 (768-2,253)	397 (225-625)	287 (162-451)	3,047 (2,148-4,137)
	Sockeye	276 (112-498)	714 (154-1,866)	675 (367-1,096)	215 (116-355)	154 (83-252)	2,034 (1,248-3,257)
	Total	787 (468-1,216)	2,023 (934-3,577)	2,716 (1,770-3,941)	806 (533-1,161)	581 (384-834)	6,914 (5,232-8,946)
6/24/2016	Chinook	0	133 (66-234)	118 (83-160)	57 (41-77)	29 (20-39)	337 (256-448)
	Chum	0	194 (80-344)	255 (147-384)	117 (72-175)	59 (36-87)	625 (450-828)
	Sockeye	0	179 (41-456)	124 (71-190)	63 (36-98)	32 (18-49)	398 (229-680)
	Total	0	507 (253-845)	496 (352-675)	238 (170-322)	119 (85-161)	1,359 (1,040-1,747)
Entire Opener	Chinook	3,208 (1,764-5,231)	3,036 (2,037-4,296)	3,738 (2,760-5,044)	1,584 (1,198-2,060)	498 (385-637)	12,065 (9,842-14,657)
	Chum	1,874 (1,247-2,637)	3,143 (2,082-4,485)	7,019 (4,350-10,495)	2,516 (1,673-3,655)	794 (573-1,056)	15,346 (12,141-19,230)
	Sockeye	2,762 (1,537-4,290)	2,628 (1,551-4,109)	2,314 (1,682-3,054)	1,041 (777-1,348)	392 (288-522)	9,136 (7,266-11,334)
	Total	7,844 (5,519-10,813)	8,807 (6,103-12,189)	13,070 (9,450-17,765)	5,141 (3,851-6,781)	1,685 (1,300-2,123)	36,546 (30,956-42,890)

[1] Geographic strata: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiakchak to Kalskag, E = Kalskag to Aniak

Table 8. Salmon harvest from the third opener (6/21/2016 – 6/24/2016) by set nets.

Day	Species	Harvest
6/21/2016	Chinook	417 (170-724)
	Chum	245 (20-625)
	Sockeye	639 (209-1,214)
	Total	1,300 (538-2,260)
6/22/2016	Chinook	243 (99-422)
	Chum	143 (11-364)
	Sockeye	373 (122-708)
	Total	758 (314-1,318)
6/23/2016	Chinook	266 (108-462)
	Chum	156 (12-399)
	Sockeye	408 (134-776)
	Total	831 (343-1,444)
6/24/2016	Chinook	139 (57-241)
	Chum	82 (7-208)
	Sockeye	213 (70-405)
	Total	433 (179-753)
Entire Opener	Chinook	1,065 (434-1,849)
	Chum	625 (50-1,596)
	Sockeye	1,633 (535-3,102)
	Total	3,323 (1,374-5,775)

Table 9. Salmon harvest from drift boat trips from the fourth opener (6/29/2016 – 7/2/2016) by species and geographic strata[1].

Date	Species	Geographic Stratum					Total
		A	B	C	D	E	
6/29/2016	Chinook	201 (130-292)	225 (146-326)	426 (176-618)	175 (113-253)	8 (5-12)	1,035 (670-1,500)
	Chum	457 (281-687)	511 (314-768)	969 (595-1,455)	397 (244-596)	18 (11-27)	2,352 (1,445-3,533)
	Sockeye	667 (429-971)	747 (480-1,086)	1,414 (910-2,058)	580 (373-843)	26 (17-38)	3,434 (2,209-4,997)
	Total	1,326 (933-1,804)	1,483 (1,043-2,018)	2,809 (1,976-3,822)	1,151 (810-1,567)	52 (37-71)	6,822 (4,799-9,283)
6/30/2016	Chinook	77 (32-148)	123 (50-235)	201 (83-385)	56 (23-108)	4 (2-8)	462 (190-883)
	Chum	193 (74-386)	307 (117-613)	503 (192-1,005)	141 (54-282)	10 (4-21)	1,155 (440-2,307)
	Sockeye	484 (239-822)	769 (379-1,307)	1,261 (622-2,144)	354 (175-602)	26 (13-44)	2,893 (1,428-4,290)
	Total	754 (396-1,226)	1,198 (630-1,949)	1,965 (1,033-3,197)	552 (290-898)	40 (21-66)	4,510 (2,371-7,335)
7/1/2016	Chinook	45 (18-90)	99 (40-197)	182 (73-361)	34 (14-67)	0	360 (145-715)
	Chum	239 (106-445)	524 (232-975)	960 (425-1,787)	179 (79-333)	0	1,903 (842-3,539)
	Sockeye	472 (230-859)	1,034 (505-1,882)	1,897 (926-3,451)	354 (173-644)	0	3,757 (1,834-6,836)
	Total	756 (383-1,318)	1,657 (841-2,890)	3,039 (1,541-5,298)	567 (288-989)	0	6,019 (3053-10,494)
7/2/2016	Chinook	0	0	35 (14-62)	6 (3-11)	0	41 (17-73)
	Chum	0	0	419 (223-659)	72 (39-114)	0	491 (262-773)
	Sockeye	0	0	392 (220-619)	68 (38-107)	0	460 (258-726)
	Total	0	0	845 (534-1,222)	146 (93-212)	0	992 (627-1,434)
Entire Opener	Chinook	324 (221-448)	447 (299-628)	844 (578-1,165)	271 (187-372)	12 (8-17)	1,898 (1,297-2,622)
	Chum	889 (593-1,242)	1,342 (869-1,933)	2,851 (1,973-3,935)	790 (551-1,073)	28 (18-42)	5,901 (4,033-8,181)
	Sockeye	1,623 (1,097-2,241)	2,550 (1,676-3,639)	4,963 (3,390-6,928)	1,355 (943-1,837)	52 (33-75)	10,543 (7,160-14,694)
	Total	2,836 (1,990-3,803)	4,339 (2,946-5,984)	8,658 (6,146-11,610)	2,417 (1,747-3,174)	93 (63-128)	18,342 (12,921-24,639)

[1] Geographic strata: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiakchak to Kalskag, E = Kalskag to Aniak

Table 10. Salmon harvest from the fourth opener (6/29/2016 – 7/2/2016) by set nets.

Day	Species	Harvest
6/29/2016	Chinook	12 (0-32)
	Chum	423 (22-1,176)
	Sockeye	377 (72-1,030)
	Total	812 (180-2,250)
6/30/2016	Chinook	23 (0-61)
	Chum	798 (42-2,222)
	Sockeye	712 (137-1,946)
	Total	1,534 (339-4,251)
7/1/2016	Chinook	11 (0-29)
	Chum	376 (20-1,046)
	Sockeye	335 (65-916)
	Total	722 (160-2,000)
7/2/2016	Chinook	3 (0-7)
	Chum	94 (5-261)
	Sockeye	84 (16-229)
	Total	180 (40-500)
Entire Opener	Chinook	50 (0-129)
	Chum	1,691 (90-4,705)
	Sockeye	1,508 (290-4,122)
	Total	3,248 (718-9,002)

Table 11. Total salmon harvest by geographic stratum[1] across all four openers. This includes harvest from both drift boat trips and set nets.

Species	Geographic Stratum					Total
	A	B	C	D	E	
Chinook	9,225 (5,919-13,508)	6,491 (4,232-9,382)	7,689 (5,297-10,743)	3,649 (2,663-4,855)	965 (764-1,286)	28,019 (18,878-39,774)
Chum	4,590 (2,823-6,840)	5,628 (3,377-8,737)	11,848 (6,788-19,052)	4,473 (2,562-7,354)	859 (607-1,163)	27,398 (16,157-43,146)
Sockeye	5,348 (3,090-8,226)	6,143 (3,584-9,735)	9,695 (5,796-15,189)	3,372 (2,048-5,357)	468 (328-643)	25,026 (14,848-39,150)
Total	19,163 (11,834-28,574)	18,262 (11,196-27,854)	29,232 (17,881-44,984)	11,494 (7,273-17,566)	2,292 (1,699-3,092)	80,443 (49,883-122,070)

[1] Geographic strata: A = Below Johnson River, B = Johnson River to Napaskiak, C = Napaskiak to Akiachak, D = Akiakchak to Kalskag, E = Kalskag to Aniak